SEASONAL AND ANNUAL VARIATION OF SOME CHEMICALS IN FORAGE IN THE VICINITY OF THE NANTICOKE INDUSTRIAL COMPLEX 1978 to 1985

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SEASONAL AND ANNUAL VARIATION OF SOME CHEMICALS IN FORAGE IN THE VICINITY OF THE NANTICOKE INDUSTRIAL COMPLEX. 1978 TO 1985

Background Information

Nanticoke is a rural village located approximately 50 km south of Hamilton on the north shore of Lake Erie. Historically the land use has been agricultural, although the area was chosen as the site of a major industrial development initiated in the 1970's. Ontario Hydro commissioned the first of eight 500 MW units in 1973 and construction was completed by 1978. The Nanticoke generating station is one of the largest coal-fired thermal power plants in the world. Construction of the Texaco oil refinery with a planned capacity of 160,000 barrels/day began in 1974 and the plant became operational in 1978. Stelco began construction of their Lake Erie Works steel-making complex in 1974 and were in limited production in June, 1980. The first stage of the steel mill has a design capacity of over one million tons of slab steel.

Since 1971, the Phytotoxicology Section has conducted a variety of terrestrial environmental studies in the Nanticoke area to assess the impact of industrial emissions on the surrounding forests and agricultural communities. The combustion of coal, the refining of oil and the manufacture of steel produce emissions which include oxides of sulphur and nitrogen, fluoride, a large number of

light and heavy metals and possibly some trace rare-earth elements. The sulphur and nitrogen oxides are, in turn, precursors of either acidic precipitation or ozone which contribute to the regional, transboundary transport phenomena.

The Phytotoxicology assessment studies have included annual chemical analysis of white ash tree foliage and periodic soil sampling to determine regional chemical deposition relative to distance and direction from the three major Nanticoke industries. In addition, permanent plots of pollution sensitive tree species have been established to monitor acute air pollution episodes. Also, an inspection of sensitive indigenous plants is conducted several times each growing season to check for air pollution injury symptoms.

Many of the farms to the north and east of the industrial complex are currently involved in the production of beef or the maintenance of dairy herds. Therefore, in 1978 a survey was initiated to monitor the fluoride and heavy metal content of forage which provides the bulk of fresh and winter feed stock of cattle in the area. This report deals only with the results of these forage collections from 1978 to 1985.

From 1978 to 1981 forage was collected from as many as 14 sites periodically throughout the growing season. From 1982 to the present, forage was collected from 9 common sites at the end of each of the 7 months in the growing season, April to October, inclusive. The forage samples were collected using standard field methodology and processed in the Phytotoxicology laboratory on a not-washed basis, as would be the manner in cattle consumption. Over the last eight years forage has been analyzed for 15 elements. These were selenium (Se), molybdenum (Mo), mercury (Hg), fluoride (F), sulphur (S), chlorine (Cl), arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), vanadium (V), copper (Cu), zinc (Zn), nickel (Ni) and iron (Fe). Forage was not analyzed for all of these elements each year; rather, different elements were periodically introduced into the analytical stream in an attempt to identify a chemical tracer which may show a concentration gradient from one of the three main sources comprising the Nanticoke Industrial Complex.

Analytical Results

The locations of the nine common forage sites are illustated in Figure 1. They are situated mostly to the east and northeast of the sources, as the predominant growing season wind is from the west-southwest. The forage chemical data are summarized in a series of tables with a similar format. Adjacent to the site number is the direction and distance in km from the centre of the Village of

Nanticoke. All chemical concentrations are based on not washed forage, oven-dried, and presented in parts per million (ppm), except in a few instances where the levels are given in per cent.

On each chemical data table are a series of numbers to which the concentrations at the various sample sites are compared. This comparative data base is called the Phytotoxicology Upper Limits of Normal. Chemical concentrations will vary in forage from place to place and from time to time even in the absence of an industrial air pollution source. The upper limit of this natural variation can be accurately predicted by calculating the average value of all the background or control forage samples and adding three standard deviations. Statistically this represents 99% of all natural variation within the sampled population. Concentrations above these levels can usually be associated with an extraneous contamination source.

Annual Variation: 1978

Table 1 lists the As, F, Se, Cl and S concentrations of forage collected during the mid summer of 1978. At this time the Ontario Hydro generating plant was producing electricity intermittently and the Texaco refinery had just been completed. The Stelco steel mill was not opperational. The F, Se, Cl and S forage concentrations did not exceed background levels at any of the collection sites. There is no background level for As because an insufficient number of control samples have been analyzed for this element. There was no tendency towards decreasing chemical concentrations with increasing distance from the source industries for F, Cl, As and S. However, the Se concentration at Site 024, (2 km NNE of the Village of Nanticoke but adjacent to the south boundary of the Texaco refinery), was 0.47 ppm. This level was two or more times higher than the other 8 sampling sites and only marginally below the 0.50 ppm upper limit of normal. The Se concentration of forage from other sites in the vicinity of the Nanticoke industries were not similarly elevated. In fact, Se levels in forage from the most distant sites ranged from 0.19 ppm to 0.25 ppm, which were slightly higher than the sites adjacent to the industries but lower than the 0.47 ppm detected at Site 024.

Even though Texaco began operations in 1978 it is aoubtful that refinery emissions contributed to the elevated Se in forage at Site 024 because Se levels at this and all other sites remained consistently much lower in all subsequent sampling years. For example the average Se concentration from all 9 sample sites in 1978 was 0.23. In 1979 the average fell to 0.10 ppm and never exceeded 0.07 ppm through to 1985, during years of full production at Texaco. The average

growing season data for Se and 14 other elements are summarized in Table 2. The mean Se concentrations detected in forage at each of the 9 sample sites during the summer of 1978 are illustrated in Figure 2.

Annual Variation: 1979

The forage was analyzed for the same 5 chemicals in 1979. The forage samples in this year were also collected in mid summer. The 1979 chemical concentrations were slightly lower than the 1978 levels. Similarly, none of the samples exceeded the normal background values nor was there a tendency towards decreasing elemental concentration with increasing distance from the Nanticoke Industrial Complex. Table 3 summarizes the 1979 data. The Se concentration was 0.10 ppm at all 9 sampling locations.

Annual Variation: 1980

In 1980 the analyses were expanded to include Pb, Cd, Mo, and Hg. These metals are present in coal in trace concentrations and therefore may be associated with emissions from the Nanticoke generating station. Table 4 summarizes the 1980 forage data, again collected in mid summer. None of the chemical concentrations exceeded the background limit, in fact, Cd and Hg levels were consistently at or below their respective analytical detection limits. There was no relationship between any of the chemical concentrations and distance or direction from the Nanticoke Industrial Complex.

Annual Variation: 1981

In 1981 the analyses were expanded again to include Cr, V, Cu, Zn and Fe. At this time the Stelco steel mill was in operation. Table 5 summarizes the 1981 forage chemical data. The forage samples were collected in mid summer, as were the previous three years' data. Copper (11 ppm) and Zn (50 ppm) forage concentrations exceeded background ranges at Site 061, located about 8.1 km E of the Village of Nanticoke near Selkirk Provincial Park. Chlorine (0.96%) was also elevated relative to the other sample locations at Site 061 but it did not exceed the background range of 1.00%.

The Fe concentration of forage at Site 047, situated about 8.3 km NE of Nanticoke near Cheapside, was 610 ppm. This was considerably higher than at the

other sites and exceeded the background range of 500 ppm. There was a slight tendency towards higher forage Fe levels in the vicinity of the Stelco steel mill, with the obvious exception of the anomalously high result at Site 047. The Fe concentration of forage and other plants growing close to the ground can vary considerably because of contamination by blowing soil particles which can often contain Fe in the low per cent range. Forage is usually processed not washed to simulate ungulate consumption; therefore, adhering soil particles may increase the variation of the analytical results. This is reflected in the relatively high upper limit of normal of 500 ppm. The anomalously elevated Fe level of 610 ppm at Site 047 in 1981 was attributed to fugitive soil contamination and not to emissions from the Nanticoke industries.

Annual Variation:1982

In 1982 the frequency of forage sampling was increased to three collections from one: late spring (end of May), mid-summer (end of July) and early fall (end of September). The chemical tests were reduced to 5 and included S, Se, F, Cl and Fe. The F levels in forage remained relatively constant throughout the summer. The levels tended to be highest at Site 023, about 1.1 km E of Nanticoke. The levels approached but did not exceed the background range for the May (12 ppm) and July (11 ppm) collections at this site but fell away to 4 ppm by the end of the growing season. These data are summarized in Table 6.

Table 7 summarizes the Cl data for 1982. The data show a consistent rise in forage Cl concentrations at almost all sites as the growing season progresses. The background range of 1.00% is exceeded at Sites 004 (1.17%), 061 (1.13%) and 064 (1.07%) during the September forage collection. There was no apparent Cl gradient relative to the sources; in fact, the highest concentration (1.17%) was detected upwind of the Nanticoke Industrial Complex.

Sulphur, Se and Fe concentrations in forage (Table 8 and 9, respectively) tended to decrease slightly in the middle of the growing season and to peak during the September collections. None of the Se levels exceeded the background range nor was there an apparent concentration gradient relative to the Nanticoke sources.

The Fe concentration of forage at Site 002, 0.4 km W of the Village of Nanticoke and closest to and directly downwind of the Stelco steel mill, was 700 ppm in September. The next highest Fe level was 140 ppm which occurred at both Sites 023 and 061. The 1982 growing season mean Fe concentration of forage from Site 004 was 299 ppm, almost twice as high as the next highest mean level of 163

ppm at Site 023 which is the next farthest site downwind of Stelco. By 1982 it was apparent that Stelco was the source of elevated Fe levels in forage in the vicinity of the Village of Nanticoke.

The S concentration of forage exceeded the background range at two locations in September: Site 023 (0.59%) very close to the Nanticoke industries, and at Site 064 (0.53%) over 11 km from Nanticoke. Of the total SO_2 emissions from the Nanticoke industries, Ontario Hydro contributes about 94%, Texaco about 4% and Stelco about 2%. Emissions from the generating station are released from two 198 m stacks. Computer modelling has predicted that the maximum ground level concentration from Ontario Hydro emissions occurs between 8 and 11 km from the source. The considerable distance usually required for the generating station's emissions to reach the ground is a function of the very high stacks and meteorological conditions which prevail along the Lake Erie shoreline. Air monitoring data have shown that the stations which most frequently record the highest ambient SO_2 concentrations are located between 7 and 11 km NE of the generating station (Sahota, H., P. Kiely and M. Lusis. 1985. Air Quality Impact of the Nanticoke Industrial Development. J. Water, Air and Soil Pollution, 25, pg. 249-263). This information is consistent with elevated levels of S in forage occurring more frequently at the more distant sample sites.

Annual Variation: 1983

The sampling frequency was increased again to 7 collections at the end of consecutive months, April to October, inclusive. In 1983 Hg was again added to the analytical test load. The other 1983 chemical tests included S, Se, F, Cl and Fe. The 1983 Hg data are summarized in Table 11. There appears to be no relationship between the Hg concentration of forage and the Nanticoke sources. Mercury levels remained at or near the analytical detection limit of 0.01 ppm for May, June and July, then increased by a factor of 10 or more at most sites in August and fell abruptly in September and October. The highest Hg levels were recorded at stations either upwind or farthest away from Nanticoke.

Fluoride levels in forage (Table 12) remained uniformly low throughout the 1983 growing season with no relation to distance or direction from the Nanticoke sources. The highest concentration was 5 ppm, detected both at the closest site (002) and the farthest site (048). Similarly, Se levels in forage in 1983 (Table 13) were uniformly low with the exception of Site 048 in August, (the most distant samling location), where forage contained 0.37 ppm. Most of the other sampling locations, in every month except September, had forage Se concentrations near or below the analytical detection limit of 0.03 ppm.

The 1983 Cl and S data are summarized in Tables 14 and 15, respectively. Both chemicals tend to increase as the growing season progresses and the sample sites with the highest levels tend to be the middle distance locations, i.e. 061 and 047, at a little more than 8 km fron Nanticoke. Although the upper limit of normal guideline was exceeded for both Cl and S there was no consistent relationship with distance or direction from the source industries.

The 1983 Fe data are summarized in Table 16. Iron concentrations in forage were uniformly low early in the growing season and tended to increase gradually until August when levels at Site 023, 1.1 km E of Nanticoke increased dramatically to 1600 ppm from 100 ppm the previous month. Forage Fe concentrations at this site remained high in September (1450 ppm) and decreased to 450 ppm by the end of the growing season in October. The seasonal mean Fe concentration of forage at Site 023 in 1983 was 645 ppm. The next highest growing season mean Fe concentration was 204 ppm at Site 002, 0.4 km W of Nanticoke. These sites are the two closest locations to the Stelco steel mill.

Annual Variation: 1984

In 1984 F (Table 17), and Hg (Table 18) concentrations in forage remained low throughout the growing season. Se levels (Table 19) were below the analytical detection limit of 0.03 ppm at most sites for the first five months but rose abruptly to 0.29 ppm at Site 002, (0.4 km W) in September and increased marginally to 0.30 ppm in October at the same site. Levels of 0.30 ppm Se in forage also occurred in October at Sites 047 and 048, two of the most distant sites. Se is a trace element contaminant of coal, and thus possibly associated with emissions from the generating station. Elevated Se levels at the more distant sites would seem to support this relationship. However, similar levels of Se at the two closest sites suggest a possible contribution from the Stelco mill. Regardless of any apparent gradient, the Se concentrations in forage are well below the upper limit of normal and therefore do not represent contamination of any environmental significance.

The Fe concentration of forage at the two closest sites in October of 1984 was 690 ppm (Site 002, 0.4 km W) and 3600 ppm (Site 023, 1.1 km E). The mean Fe concentration for all nine sites in October was 717 ppm and the mean growing season Fe level of forage at Site 023 was 1194 ppm. The Fe data are summarized in Table 20. Figure 4 illustrates the Fe concentration of forage at the 9 sample sites in October, 1984. The three sites closest to Stelco exceed the 500

ppm upper limit of normal. Site 023, at 3600 ppm, exceeded this guideline by more than a factor of 7. The high levels of Fe in forage in the vicinity of the village of Nanticoke are undoubtedly related to periodic particulate emissions from Stelco.

The S (Table 21) and Cl (Table 22) levels in forage varied considerably throughout the 1984 growing season. Sulphur concentrations above the background range occurred 5 times, all at the more distant sites. Cl concentrations above the background range occurred 8 times, also at the more distant sites. The forage collected in October of 1984 was not analyzed for Cl because of insufficient sample size. The Cl data remain somewhat enigmatic. Natural background concentrations of this element are quite variable, which is reflected by the high (1.0%) upper limit of normal guideline. However, this guideline is frequently exceeded, usually at the more distant sample sites. Therefore, if these elevated concentrations are associated with industrial emissions the most probable source would be the Ontario Hydro Nanticoke generating station.

Annual Variation: 1985

The Se concentration in forage was below the analytical detection limit of 0.03 ppm at every site for six of the seven sampling months in 1985. Only in May were Se levels measurable, and even then only in marginally elevated concentrations. The highest levels occurred at the most distant sites (0.12 ppm, site 061, 8.1 km E), suggesting a possible relationship with the generating station, although the 0.5 ppm guideline was not exceeded. The Se data are summarized in Table 23.

The F concentrations in forage in 1985 were generally very low with marginally elevated levels detected in August and September at the sites closest the Stelco steel mill. None of the levels exceeded the 12 ppm guideline. The F data are summarized in Table 24.

The Hg forage concentrations were variable but very low. There was no apparent deposition pattern. The Hg data are summarized in Table 25.

Molybdenum was again added to the analytical stream in 1985. The Mo data are summarized in Table 26. Molybdenum is another trace element associated with coal combustion. Although Mo levels in forage were quite variable, none exceeded the 6 ppm upper limit of normal guideline and the sites with marginally elevated concentrations tended to be the sample locations upwind and beyond 8 km.

The 1985 Fe data are summarized in Table 27. The Fe concentration of forage generally was much lower in 1985 than the previous few years. The 500 ppm

guideline was not exceeded at any of the sites, although it was equalled at Site 024 in October. The sample sites with the three highest growing season mean concentrations were the three sites closest the Stelco mill.

The growing season mean S concentration of forage in 1985 was 0.36%. This was the highest mean value since forage sampling commenced in 1978 (refer to Table 2). The upper limit of normal guideline was exceeded at several sites in July and August and at Site 047 in September and October. The 1985 S data are summarized in Table 28 and the S concentration in forage for October is illustrated in Figure 5. These data re-affirm that although S levels are generally low, elevated concentrations indicative of industrial emissions do occur. These elevated levels tend to happen at the more distant sample locations, which suggest deposition from the Ontario Hydro generating station.

Growing Season Mean Data

Forage from the Nanticoke area has been analyzed for F and Se since 1978. Tables 29 and 30 summarize the mean growing season F and Se (respectively) concentration of forage from 1978 to 1985 for each of the nine common sample sites. The year of highest F levels was 1982, although no single sites averaged greater than 9 ppm and the mean of all sites was only 6 ppm. Average F concentrations were at or near the detection limit at all sites in 1985. There is no tendency towards increasing F concentrations with time. Figure 5 illustrates the mean F concentration from each of the nine sites for the period 1978 to 1985. Although individual months in several years showed F gradients relative to the Nanticoke industries the 8-year mean data revealed no such relationship.

The growing season mean Se concentrations in forage were highest in 1978 and lowest in 1985. None of the mean Se values exceeded the upper limit of normal guideline and there was a slight tendency towards marginally elevated levels at the sites furthest from the Nanticoke industries. Also, there was a declining Se gradient with time. The 8-year mean Se concentration for each of the nine sample sites are illustrated in Figure 6.

The growing season mean S data are summarized in Table 31. The maximum concentration (0.66%, Site 061) occurred in 1978 but 1985 had the highest 9-site mean (0.36, 1985 vs. 0.35, 1978). There was no time gradient and, although individual months displayed gradients relative to the generating station, no such distribution was evident for the 8-year mean data for each site (illustrated in Figure 7).

Iron was the only element for which a consistent depostion gradient was identified. Table 32 summarizes the growing sean mean Fe concentrations in forage from 1981 to 1985. Forage was not analyzed for Fe previous to 1981. The yearly mean data fluctuated considerably, ranging from a minimum of 124 ppm in 1982 to a maximum of 290 ppm in 1984. In each year the highest concentrations occurred at one of the two sites closest to and directly downwind of Stelco. Figure 8 illustrates the 5-year mean concentration at the nine sample sites and clearly displays the deposition gradient relative to the steel mill.

Elemental Variation Within The Growing Season

Monthly mean concentrations for F, Se, S and Fe were calculated for each of the nine sample sites for the years 1982 to 1985. The F data are summarized in Table 33. There was no relationship between sample time within the growing season and the sample location. The 9-site monthly mean data varied only marginally.

The Se monthly data are summarized in Table 34. Although the Se forage concentrations were low at all sites in all months and none exceeded the upper limit of normal guideline, the highest mean values occurred in the last two months of the growing season. Similary, the mean S data fluctuated during the first half of the growing season and tended to increase in August, September and October. The most significant increases tended to occur at the sites about 8 km from the village of Nanticoke, relative to the known deposition patterns of the Ontario Hydro generating station. The S monthly growing season data are summarized in Table 35.

The Fe concentration of forage tended to be elevated early in the growing season, then declined marginally in June and July and increased substantially during the last three months. The elevated values in April and May are likely associated with higher fugitive dust levels from ploughed fields before crop establishment. The higher Fe levels towards the end of the growing season likely reflect accumulated source deposition. The Fe data are summarized in Table 36.

Forage Quality For Cattle Consumption

Local forage provides the bulk of fresh and winter feed consumed by cattle in the Nanticoke area. The Phytotoxicology sampling program conducted since 1978 has shown that the vast majority of the forage consumed by local cattle

has chemical concentrations well within normal background levels. However, occasionally Cl, S, Cu, Zn and particularly Fe concentrations can exceed these background levels thereby suggesting deposition from one or more of the Nanticoke industries. Table 37 compares the maximum and mean forage chemical concentrations from the Nanticoke data base with dietary toxicity levels for cattle as reported by two separate literature references. Reference 1 in Table 37 refers to a publication entitled "Mineral Tolerance of Domestic Animals" (Subcommittee on Mineral Toxicity in Animals, Committee on Animal Nutrition, Board on Agriculture and Renewable Resources, Commission on Natural Resources, National Research Council, National Academy of Sciences, Washington, D.C., 1980). The Reference 2 data column refers to "Veterinary Trace Mineral Deficiency and Toxicity Information" (a joint publication of Agriculture Canada and the Province of British Columbia Ministry of Agriculture, Publication 5139, ISBN: 0-662-11367-5, 1981). Reference 1 data are referred to as maximum tolerance levels and do not necessarily imply acute or chronic toxicity thresholds. Reference 2 data are the lower end of the range at which chronic dietary exposure has been documented to induce toxicity.

Toxicity references are not available for Cl and S, two elements which marginally exceed the Phytotoxicology upper limit of background guidelines. The maximum Cu concentration of Nanticoke forage at 11 ppm is more than 9 times lower than the literature tolerance level for cattle of 100 ppm. The Zn concentration of Nanticoke forage averages 36 ppm, just below the normal background guideline of 40 ppm. However the maximum Zn concentration detected was 50 ppm, which is lower than the maximum tolerance level by a factor of 10 and lower than the minimum toxicity threshold by a factor of 100.

Of the 15 chemical elements examined in Nanticoke forage since 1978 only Fe has been consistently elevated at specific sample sites. Although the mean Fe concentration from all sample locations was 197 ppm, the mean levels for Site 023 in 1983 and 1984 were 645 ppm and 1194 ppm, for a 5-year (1981-1985) mean value of 487 ppm. The maximum Fe concentration of 3600 ppm occurred in October 1984 at Site 023. The mean concentration at this site in 1984 (1194 ppm) exceeded the tolerance level of 1000 ppm but was well below the 4000 ppm toxicity threshold. However, reference 2 explains that little data are available regarding dietary Fe levels and that no toxic effects directly attributable to iron have been reported. This reference also states it is possible that Co, Cu, Zn Mn or Se deficiency could be induced by high dietary Fe intact. Drinking water containing greater than 10 mg Fe per litre has been reported to reduce total water intake by cattle resulting in reduced milk production.

In the spring of 1985 the Phytotoxicology Section conducted a joint investigation with the Ministry of Agriculture and Food regarding cattle death on a farm in the Nanticoke area. Water, forage and feed samples were collected and analyzed for 23 chemical parameters, including all 15 of the elements listed in this report. The farm was located within the area of elevated Fe deposition identified by Phytotoxicology survey results. The cattle were dairy cattle. The Fe concentration of hay stored outside averaged 1220 ppm, barn water from an inside tap contained 0.32 mg/l Fe and pond water just outside the barn had an Fe concentration of 0.63 mg/l. The chemical concentration of hay from this farm was typical of the results summarized in this report for Nanticoke area forage. The chemical data were reviewed by OMAF cattle specialists who concluded the forage was completely acceptable for cattle consumption and that the feed stock was in no way related to the cattle death. An autopsy performed by OMAF veterinarians in conjunction with the University of Guelph concluded the cattle death was disease related and that air pollution was not implicated.

Therefore, although elevated levels of some chemicals occasionally occur in forage in the Nanticoke area, and these elevations are likely attributted to deposition of industrial emissions, the forage is acceptable for cattle consumption. However, Fe concentrations in forage in the vicinity of the Stelco steel mill should be monitored closely to ensure that the tendency towards increasing Fe levels observed in the past few years does not continue.

Conclusions

The Phytotoxicology Section has collected forage from 9 common sites in the Nanticoke area since 1978. During this time forage has been analyzed for as many as 15 chemical elements. Occasionally Cl, S, Cu and Zn concentrations marginally exceeded the normal background levels for these elements. Sulphur exceedences tended to occur most frequently at the more distant sampling locations. Iron was the only element to show a consistent deposition gradient relative to the Nanticoke industries and to be detected in significantly elevated concentrations. The source of excessive Fe deposition in the vicinity of the village of Nanticoke was the Stelco steel mill. The maximum Fe concentration and the growing season mean Fe level of forage from the two sample sites closest Stelco were sufficiently elevated to warrant continued monitoring. Even though Fe levels were high at some sites it was concluded by OMAF cattle specialists that forage in the Nanticoke area was acceptable for cattle consumption.

TABLE 1: CHEMICAL CONCENTRATION* OF FORAGE COLLECTED MID-SUMMER, 1978

Site No.	Distance & Direction**	As	F	Se	Cl (%)	S (%)
002	0.4 W	0.12	2	0.15	0.40	0.24
023	1.1 E	0.16	2	0.17	0.17	0.32
024	2.0 NNE	0.13	3	0.47	0.62	0.25
004	3.6 W	0.12	3	0.17	0.88	0.34
044	4.6 E	0.11	3	0.24	0.48	0.32
061	8.1 E	0.07	3	0.19	0.83	**0.66**
047	8.3 NE	0.09	9	0.20	0.35	0.35
064	11.3 ENE	0.19	3	0.19	0.65	0.32
048	12.1 NE	0.25	4	0.25	0.46	0.39
Mean		0.14	4	0.23	0.54	0.35
Phytotoxicology Upper Limit of Normal***		NE	12	0.50	1.00	0.50

* Not washed, oven-dried, parts per million except where noted (Cl & S)

** km from the village of Nanticoke

*** See explanation in text

NE Not established

TABLE 2: AVERAGE GROWING SEASON CHEMICAL CONCENTRATION OF FORAGE, 1978 TO 1985*

Chemical	Year/Concentration								Phytotoxicology Upper Limit of Normal
	1978	1979	1980	1981	1982	1983	1984	1985	
As	0.14	0.10	0.30	0.15	NA	NA	NA	NA	NE
F	4	3	2	3	6	2	3	2	12
Se	0.23	0.10	0.07	0.03	0.06	0.03	0.06	BD	0.5
Cl (%)	0.54	0.55	0.36	0.45	0.58	0.56	0.68	NA	1.0
S (%)	0.35	0.27	0.24	0.29	0.33	0.31	0.34	0.36	0.5
Pb	NA	NA	2	3	NA	NA	NA	NA	20
Cd	NA	NA	BD	BD	NA	NA	NA	NA	0.1
Mo	NA	NA	2	1	NA	NA	NA	1	6
Hg	NA	NA	0.01	NA	NA	0.04	0.02	0.05	NE
Cr	NA	NA	NA	1	NA	NA	NA	NA	5
V	NA	NA	NA	BD	NA	NA	NA	NA	6
Cu	NA	NA	NA	5	NA	NA	NA	NA	7
Zn	NA	NA	NA	36	NA	NA	NA	NA	40
Ni	NA	NA	NA	1	NA	NA	NA	NA	5
Fe	NA	NA	NA	237	127	188	290	144	500

* Mean of all 9 sites, multiple collections, parts per million (except where noted), not washed, dry weight

NE Not established
NA Not analyzed
BD Below analytical detection limit; Cd = 0.1 ppm, V = 1 ppm, Se = 0.01 ppm

TABLE 3: CHEMICAL CONCENTRATION OF FORAGE COLLECTED MID-SUMMER, 1979*

Site No.	Distance & Direction**	As	F	Se	Cl (%)	S (%)
002	0.4 W	0.1	3	0.10	0.69	0.17
023	1.1 E	0.1	4	0.10	0.37	0.36
024	2.0 NNE	0.1	3	0.10	0.81	0.47
004	3.6 W	0.1	3	0.10	0.21	0.15
044	4.6 E	0.1	3	0.10	0.78	0.13
061	8.1 E	0.1	3	0.10	0.28	0.33
047	8.3 NE	0.1	4	0.10	0.54	0.23
064	11.3 ENE	0.1	4	0.10	0.98	0.28
048	12.1 NE	0.1	4	0.10	0.30	0.35
Mean		0.1	3	0.10	0.55	0.27
Phytotoxicology Upper Limit of Normal***		NE	12	0.50	1.00	0.50

* Not washed, oven-dried, parts per million except where noted (Cl & S)

** km from the village of Nanticoke

*** See explanation in text

NE Not established

TABLE 4: CHEMICAL CONCENTRATION* OF FORAGE COLLECTED IN MID-SUMMER, 1980

Site No	Distance & Direction**	As	F	Pb	Cd	Mo	Se	Cl (%)	S (%)	Hg
002	0.4 W	0.3	6	2	BD	2	0.05	0.29	0.22	0.01
023	1.1 E	0.3	1	4	BD	2	0.06	0.25	0.29	0.01
024	2.0 NNE	0.3	1	2	BD	3	0.06	0.56	0.25	0.01
004	3.6 W	0.3	2	2	BD	2	0.05	0.17	0.21	0.01
044	4.6 E	0.3	1	2	BD	2	0.13	0.43	0.16	0.01
061	8.1 E	0.3	1	2	BD	2	0.07	0.25	0.27	0.01
047	8.3 NE	0.3	4	2	BD	2	0.07	0.43	0.27	0.01
064	11.3 ENE	0.3	1	2	BD	2	0.10	0.66	0.23	0.01
048	12.1 NE	0.3	1	2	BD	2	0.05	0.20	0.23	0.01
Mean		0.3	2	2	BD	2	0.07	0.36	0.24	0.01
Phytotoxicology Upper Limit of Normal***		NE	12	20	0.5	6	0.50	1.00	0.50	NE

* Not washed, oven-dried, parts per million except where noted (Cl & S)

** km from the village of Nanticoke

*** See explanation in text

NE Not established

BD Below analytical detection limit; Cd = 0.1 ppm

TABLE 5: CHEMICAL CONCENTRATION* OF FORAGE COLLECTED IN MID-SUMMER, 1981

Site No	Distance & Direction**		As	Cr	F	Pb	V	Cd	Cu	Mo	Se	Zn	Cl (%)	Fe	Ni	S (%)
002	0.4	W	0.15	1	3	3	BD	BD	7	1.1	BD	34	0.64	358	1	0.30
023	1.1	E	0.15	1	2	3	BD	BD	4	1.4	BD	39	0.52	218	1	0.30
024	2.0	NNE	0.12	1	2	3	BD	BD	5	1.4	BD	39	0.40	137	1	0.30
004	3.6	W	0.15	2	2	3	BD	BD	3	0.9	BD	21	0.27	148	2	0.30
044	4.6	E	0.07	BD	3	3	BD	BD	5	0.8	BD	34	0.27	84	1	0.40
061	8.1	E	0.12	1	4	3	BD	0.1	**11**	1.3	BD	**50**	0.96	226	1	0.40
047	8.3	NE	0.21	1	7	2	1	BD	3	0.6	BD	**41**	0.26	**610**	1	0.20
064	11.3	ENE	0.26	3	4	3	BD	BD	3	0.6	0.15	28	0.13	101	2	0.20
048	12.1	NE	0.10	1	4	2	BD	0.1	6	0.7	BD	40	0.63	255	1	0.20
Mean			0.15	1	3	3	BD	BD	5	1.0	0.03	36	0.45	237	1	0.29
Phytotoxicology Upper Limit of Normal***			NE	5	12	20	6	0.5	7	6	0.50	40	1.00	500	5	0.50

* Not washed, oven-dried, parts per million except where noted (Cl & S)

** km from the village of Nanticoke

*** See explanation in text

NE Not established

BD Below analytical detection limit; Cr = 1 ppm, V = 1 ppm, Cd = 0.1 ppm, Se = 0.03 ppm

TABLE 6: SEASONAL VARIATION OF FLUORIDE IN FORAGE, 1982

Site No.	Distance & Direction**	Fluoride Concentration* May	July	September	Site Mean
002	0.4 W	6	5	5	5
023	1.1 E	12	11	4	9
024	2.0 NNE	5	6	3	5
004	3.6 W	3	6	4	4
044	4.6 E	5	6	4	5
061	8.1 E	3	6	5	5
047	8.3 NE	4	6	5	5
064	11.3 ENE	3	6	7	5
048	12.1 NE	4	2	4	7
Monthly Mean		5	6	5	6
Phytotoxicology Upper Limit of Normal***				. . . 12 ppm . . .	

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 7: SEASONAL VARIATION OF CHLORIDE IN FORAGE, 1982

Site No.	Distance & Direction**	Chloride Concentration* May	July	September	Site Mean
002	0.4 W	0.28	0.34	0.77	0.46
023	1.1 E	0.51	0.62	0.89	0.67
024	2.0 NNE	0.30	0.60	0.83	0.60
004	3.6 W	0.22	0.70	1.17	0.70
044	4.6 E	0.17	0.20	0.11	0.16
061	8.1 E	0.41	0.90	1.13	0.81
047	8.3 NE	0.39	0.55	0.73	0.56
064	11.3 ENE	0.38	0.45	1.07	0.63
048	12.1 NE	0.49	0.58	0.82	0.63
Monthly Mean		0.36	0.55	0.84	0.58
Phytotoxicology Upper Limit of Normal***			. . . 1.00% . . .		

* Not washed, oven-dried, per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 8: SEASONAL VARIATION OF SELENIUM IN FORAGE, 1982

Site No.	Distance & Direction**	Selenium Concentration* May	July	September	Site Mean
002	0.4 W	BD	BD	0.11	0.05
023	1.1 E	0.04	BD	0.11	0.06
024	2.0 NNE	0.03	BD	0.07	0.04
004	3.6 W	0.07	BD	0.07	0.05
044	4.6 E	0.06	BD	0.09	0.06
061	8.1 E	0.04	BD	0.11	0.04
047	8.3 NE	0.03	BD	0.09	0.05
064	11.3 ENE	0.06	BD	0.17	0.08
048	12.1 NE	0.04	BD	0.36	0.14
Monthly Mean		0.04	BD	0.13	0.06
Phytotoxicology Upper Limit of Normal***			. . . 0.50 ppm . . .		

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.03 ppm

TABLE 9: SEASONAL VARIATION OF IRON IN FORAGE, 1982

Site No.	Distance & Direction**	Iron Concentration* May	July	September	Site Mean
002	0.4 W	150	48	700	299
023	1.1 E	158	182	150	163
024	2.0 NNE	113	100	140	118
004	3.6 W	67	146	100	104
044	4.6 E	80	66	110	85
061	8.1 E	76	40	140	85
047	8.3 NE	81	47	70	76
064	11.3 ENE	50	29	120	66
048	12.1 NE	136	125	120	127
Monthly Mean		101	87	183	124
Phytotoxicology Upper Limit of Normal***		. . . 500 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 10: SEASONAL VARIATION OF SULPHUR IN FORAGE, 1982

Site No.	Distance & Direction**	Sulphur Concentration* May	July	September	Site Mean
002	0.4 W	0.38	0.18	0.49	0.34
023	1.1 E	0.38	0.46	0.59	0.41
024	2.0 NNE	0.34	0.29	0.45	0.29
004	3.6 W	0.28	0.18	0.34	0.27
044	4.6 E	0.29	0.19	0.44	0.31
061	8.1 E	0.31	0.33	0.41	0.35
047	8.3 NE	0.31	0.25	0.41	0.32
064	11.3 ENE	0.25	0.17	0.53	0.32
048	12.1 NE	0.29	0.19	0.48	0.32
Monthly Mean		0.31	0.23	0.46	0.33
Phytotoxicology Upper Limit of Normal***			. . . 0.50% . . .		

* Not washed, oven-dried, parts per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 11: SEASONAL VARIATION OF MERCURY IN FORAGE, 1983

Site No.	Distance & Direction**	Mercury Concentration* May	June	July	August	September	October	Site Mean
002	0.4 W	BD	0.01	0.01	0.17	0.02	0.03	0.04
023	1.1 E	0.01	BD	BD	0.08	0.02	0.03	0.03
024	2.0 NNE	BD	0.01	0.01	0.11	0.02	0.02	0.03
004	3.6 W	BD	0.01	BD	0.12	0.02	0.02	0.03
044	4.6 E	BD	0.02	0.01	0.13	0.01	0.04	0.04
061	8.1 E	0.01	0.01	0.01	0.11	0.01	0.02	0.03
047	8.3 NE	0.02	0.01	0.01	0.16	0.04	0.02	0.04
064	11.3 ENE	0.01	BD	0.01	0.16	0.02	0.03	0.04
048	12.1 NE	0.01	BD	0.01	0.16	0.02	0.02	0.04
Monthly Mean		0.01	0.01	0.01	0.13	0.02	0.03	0.04
Phytotoxicology Upper Limit of Normal***					. . . not established . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.01 ppm

TABLE 12: SEASONAL VARIATION OF FLUORIDE IN FORAGE, 1983

Site No.	Distance & Direction**	Fluoride Concentration* May	June	July	August	September	October	Site Mean
002	0.4 W	BD	BD	5	BD	3	8	3
023	1.1 E	BD	3	4	BD	1	BD	2
024	2.0 NNE	2	3	6	BD	4	3	3
004	3.6 W	BD	BD	4	BD	BD	3	2
044	4.6 E	BD	BD	3	BD	3	BD	2
061	8.1 E	BD	BD	3	BD	BD	BD	1
047	8.3 NE	BD	BD	4	BD	BD	BD	1
064	11.3 ENE	BD	BD	3	3	BD	BD	2
048	12.1 NE	BD	BD	5	6	5	4	4
Monthly Mean		BD	1	4	2	2	3	2
Phytotoxicology Upper Limit of Normal***					. . . 12 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 2 ppm

TABLE 13: SEASONAL VARIATION OF SELENIUM IN FORAGE, 1983

Site No.	Distance & Direction**		Selenium Concentration* May	June	July	August	September	October	Site Mean
002	0.4	W	BD	BD	BD	BD	0.03	0.03	BD
023	1.1	E	BD	BD	BD	BD	0.03	BD	BD
024	2.0	NNE	BD	0.07	BD	BD	0.03	BD	0.03
004	3.6	W	BD	BD	BD	BD	0.03	BD	BD
044	4.6	E	BD	BD	BD	BD	0.03	BD	BD
061	8.1	E	0.04	BD	BD	BD	0.08	0.03	0.03
047	8.3	NE	0.04	BD	BD	BD	BD	BD	BD
064	11.3	ENE	0.04	0.07	BD	BD	0.08	0.03	0.04
048	12.1	NE	0.07	BD	BD	0.37	0.17	BD	0.11
Monthly Mean			0.03	0.03	BD	0.05	0.06	0.02	0.03
Phytotoxicology Upper Limit of Normal***						. . . 0.5 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.03 ppm

TABLE 14: SEASONAL VARIATION OF CHLORIDE IN FORAGE, 1983

Site No.	Distance & Direction**		Chloride Concentration* May	June	July	August	September	October	Site Mean
002	0.4	W	0.24	0.36	0.46	0.53	0.80	0.88	0.55
023	1.1	E	0.64	0.45	0.68	0.60	0.70	0.60	0.61
024	2.0	NNE	0.45	0.53	0.60	0.50	0.67	0.65	0.57
004	3.6	W	0.40	0.32	0.55	0.81	0.71	0.66	0.58
044	4.6	E	0.08	0.18	0.18	0.18	0.17	0.20	0.17
061	8.1	E	0.30	0.51	0.66	**1.01**	**1.23**	0.93	0.77
047	8.3	NE	0.44	0.44	0.46	0.46	0.39	0.74	0.49
064	11.3	ENE	0.31	0.41	0.41	0.45	0.94	0.49	0.50
048	12.1	NE	0.54	0.50	0.98	0.76	0.84	0.81	0.74
Monthly Mean			0.38	0.41	0.55	0.59	0.72	0.66	0.56
Phytotoxicology Upper Limit of Normal***						. . . 1.00% . . .			

* Not washed, oven-dried, parts per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 15: SEASONAL VARIATION OF SULPHUR IN FORAGE, 1983

Site No.	Distance & Direction**		Sulphur Concentration* May	June	July	August	September	October	Site Mean
002	0.4	W	0.24	0.20	0.26	0.27	0.32	0.36	0.28
023	1.1	E	0.31	0.24	0.26	0.30	0.35	0.35	0.30
024	2.0	NNE	0.26	0.20	0.33	0.40	0.48	**0.57**	0.37
004	3.6	W	0.24	0.13	0.23	0.26	0.27	0.26	0.23
044	4.6	E	0.20	0.20	0.33	0.41	0.49	0.40	0.35
061	8.1	E	0.25	0.16	0.18	0.49	**0.60**	0.42	0.35
047	8.3	NE	0.23	0.20	0.17	**0.55**	0.24	**0.53**	0.32
064	11.3	ENE	0.25	0.15	0.21	0.31	0.37	0.46	0.29
048	12.1	NE	0.23	0.14	0.32	0.37	0.34	0.32	0.29
Monthly Mean			0.25	0.18	0.25	0.37	0.38	0.41	0.31
Phytotoxicology Upper Limit of Normal***								. . . 0.50% . . .	

* Not washed, oven-dried, parts per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 16: SEASONAL VARIATION OF IRON IN FORAGE, 1983

Site No.	Distance & Direction**		Iron Concentration* May	June	July	August	September	October	Site Mean
002	0.4	W	65	80	120	170	330	460	204
023	1.1	E	120	150	100	**1600**	**1450**	450	**645**
024	2.0	NNE	95	200	130	120	170	170	148
004	3.6	W	140	140	220	310	310	370	248
044	4.6	E	65	50	50	90	110	135	83
061	8.1	E	55	40	80	90	160	170	99
047	8.3	NE	170	60	50	140	140	180	123
064	11.3	ENE	70	40	220	70	90	110	100
048	12.1	NE	80	50	32	130	160	220	112
Monthly Mean			96	74	111	302	290	252	188
Phytotoxicology Upper Limit of Normal***						. . . 500 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 17: SEASONAL VARIATION OF FLUORIDE IN FORAGE, 1984

Site No.	Distance & Direction**	Fluoride Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	3	BD	BD	4	BD	4	3	2
023	1.1 E	BD	BD	BD	4	BD	2	BD	2
024	2.0 NNE	5	5	BD	4	BD	4	5	4
004	3.6 W	7	5	BD	3	BD	3	5	4
044	4.6 E	BD	BD	BD	2	BD	2	3	2
061	8.1 E	3	BD	BD	4	BD	4	BD	2
047	8.3 NE	BD	BD	BD	4	BD	3	BD	2
064	11.3 ENE	3	BD	BD	4	BD	3	3	2
048	12.1 NE	4	BD	BD	5	10	3	4	4
Monthly Mean		3	2	BD	4	2	3	3	3
Phytotoxicology Upper Limit of Normal***					. . . 12 ppm . . .				

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 2 ppm

TABLE 18: SEASONAL VARIATION OF MERCURY IN FORAGE, 1984

Site No.	Distance & Direction**	Mercury Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	0.01	0.02	0.02	0.01	0.02	0.01	0.03	0.02
023	1.1 E	0.01	BD	0.02	0.01	0.04	0.02	0.04	0.02
024	2.0 NNE	0.02	BD	0.02	0.03	0.04	0.03	0.02	0.02
004	3.6 W	0.01	BD	0.02	BD	0.01	0.01	0.01	0.01
044	4.6 E	0.03	BD	0.03	0.01	0.03	0.03	0.05	0.03
061	8.1 E	BD	BD	0.01	0.02	0.04	0.02	0.03	0.02
047	8.3 NE	0.01	BD	0.01	0.02	0.04	0.01	0.03	0.02
064	11.3 ENE	0.02	BD	0.01	0.02	0.04	0.01	0.02	0.02
048	12.1 NE	0.02	BD	0.01	BD	0.02	0.03	0.03	0.02
Monthly Mean		0.02	BD	0.02	0.01	0.03	0.02	0.03	0.02
Phytotoxicology Upper Limit of Normal***					. . . not established . . .				

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.01 ppm

TABLE 19: SEASONAL VARIATION OF SELENIUM IN FORAGE, 1984

Site No.	Distance & Direction**	Selenium Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	BD	BD	BD	BD	BD	0.29	0.30	0.10
023	1.1 E	BD	BD	BD	BD	BD	0.17	0.23	0.07
024	2.0 NNE	BD	BD	BD	BD	BD	0.17	BD	0.04
004	3.6 W	BD	BD	BD	BD	BD	0.17	BD	0.04
044	4.6 E	BD	BD	BD	BD	BD	0.17	0.23	0.07
061	8.1 E	BD	BD	BD	BD	BD	BD	0.23	0.05
047	8.3 NE	BD	BD	BD	BD	BD	BD	0.30	0.06
064	11.3 ENE	BD	BD	BD	0.17	BD	BD	0.16	0.06
048	12.1 NE	BD	BD	BD	0.05	BD	BD	0.30	0.06
Monthly Mean		BD	BD	BD	0.04	BD	0.11	0.20	0.06
Phytotoxicology Upper Limit of Normal***		. . . 0.50 ppm . . .							

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.03 ppm

TABLE 20: SEASONAL VARIATION OF IRON IN FORAGE, 1984

Site No.	Distance & Direction**	Iron Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	160	160	70	110	170	210	**690**	224
023	1.1 E	140	**1100**	90	110	**3000**	320	**3600**	**1194**
024	2.0 NNE	150	320	150	130	150	190	320	201
004	3.6 W	210	350	170	210	230	**714**	**620**	358
044	4.6 E	75	230	130	81	87	94	260	137
061	8.1 E	89	130	67	91	87	180	360	143
047	8.3 NE	76	120	36	40	95	110	200	97
064	11.3 ENE	77	190	57	87	72	78	150	103
048	12.1 NE	90	190	160	100	180	110	250	154
Monthly Mean		119	310	103	107	452	223	**717**	290
Phytotoxicology Upper Limit of Normal***						. . . 500 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 21: SEASONAL VARIATION OF SULPHUR IN FORAGE, 1984

Site No.	Distance & Direction**	Sulphur Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	0.41	0.20	0.18	0.34	0.31	0.34	0.30	0.30
023	1.1 E	0.39	0.24	0.24	0.26	0.31	0.38	0.28	0.30
024	2.0 NNE	0.38	0.23	0.23	0.33	0.38	0.37	0.50	0.35
004	3.6 W	0.42	0.15	0.19	0.29	0.16	0.33	0.48	0.29
044	4.6 E	0.36	0.22	0.30	0.34	0.47	0.46	0.47	0.37
061	8.1 E	0.37	0.20	0.20	0.39	**0.57**	0.40	0.31	0.35
047	8.3 NE	0.43	0.20	0.20	0.46	0.29	**0.57**	**0.55**	0.39
064	11.3 ENE	0.38	0.20	0.22	0.24	**0.51**	0.38	**0.55**	0.35
048	12.1 NE	0.45	0.18	0.26	0.33	0.47	0.39	0.42	0.36
Monthly Mean		0.40	0.20	0.22	0.33	0.39	0.40	0.43	0.34
Phytotoxicology Upper Limit of Normal***						. . . 0.50% . . .			

* Not washed, oven-dried, per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 22: SEASONAL VARIATION OF CHLORIDE IN FORAGE, 1984

Site No.	Distance & Direction**	Chloride Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	0.29	0.28	0.42	0.59	0.75	0.68		0.50
023	1.1 E	0.97	0.34	0.42	0.43	0.45	0.80	N	0.57
024	2.0 NNE	0.72	0.42	0.53	0.49	0.59	0.95	O	0.62
004	3.6 W	0.95	0.32	0.45	0.29	0.52	0.73		0.54
044	4.6 E	0.50	0.41	**1.19**	0.19	0.18	0.19	D	0.44
061	8.1 E	0.77	0.44	0.42	0.95	**1.77**	0.88	A	0.87
047	8.3 NE	**1.42**	0.52	0.44	0.60	0.39	0.71	T	0.68
064	11.3 ENE	0.74	0.46	0.49	0.40	0.91	0.64	A	0.61
048	12.1 NE	**1.39**	0.51	**1.29**	**1.09**	**2.04**	**1.45**		1.30
Monthly Mean		0.86	0.41	0.63	0.56	0.84	0.78		0.68
Phytotoxicology Upper Limit of Normal***					. . . 1.00% ppm . . .				

* Not washed, oven-dried, parts per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 23: SEASONAL VARIATION OF SELENIUM IN FORAGE, 1985

Site No.	Distance & Direction**	Selenium Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	BD	0.03	BD	BD	BD	BD	BD	BD
023	1.1 E	BD	0.03	BD	BD	BD	BD	BD	BD
024	2.0 NNE	BD	BD	BD	BD	BD	BD	BD	BD
004	3.6 W	BD	0.08	BD	BD	BD	BD	BD	BD
044	4.6 E	BD	0.03	BD	BD	BD	BD	BD	BD
061	8.1 E	BD	0.12	BD	BD	BD	BD	BD	0.03
047	8.3 NE	BD	0.03	BD	BD	BD	BD	BD	BD
064	11.3 ENE	BD	0.08	BD	BD	BD	BD	BD	BD
048	12.1 NE	BD	0.08	BD	BD	BD	BD	BD	BD
Monthly Mean		BD	0.06	BD	BD	BD	BD	BD	BD
Phytotoxicology Upper Limit of Normal***		. . . 0.5 ppm . . .							

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.03 ppm

TABLE 24: SEASONAL VARIATION OF FLUORIDE IN FORAGE, 1985

Site No.	Distance & Direction**	Fluoride Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	2	3	3	BD	6	4	BD	3
023	1.1 E	BD	3	BD	BD	3	3	BD	BD
024	2.0 NNE	4	2	3	3	6	3	BD	3
004	3.6 W	3	BD	BD	3	5	7	BD	3
044	4.6 E	BD	BD	BD	BD	3	3	BD	BD
061	8.1 E	BD	BD	BD	BD	3	2	BD	BD
047	8.3 NE	BD	BD	BD	BD	BD	2	BD	BD
064	11.3 ENE	BD	3	BD	BD	3	2	BD	BD
048	12.1 NE	3	3	BD	BD	4	4	BD	BD
Monthly Mean		BD	2	BD	BD	4	3	BD	2
Phytotoxicology Upper Limit of Normal***						. . . 12 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 2 ppm

TABLE 25: SEASONAL VARIATION OF MERCURY IN FORAGE, 1985

Site No.	Distance & Direction**	Mercury Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	0.02	0.01	BD	0.01	0.04	0.02	0.06	0.02
023	1.1 E	0.03	0.26	BD	0.23	0.05	0.02	0.05	0.09
024	2.0 NNE	0.03	0.08	0.01	0.01	0.03	0.02	0.05	0.03
004	3.6 W	0.02	0.10	BD	0.01	0.02	0.01	0.04	0.03
044	4.6 E	0.02	0.47	0.01	0.01	0.06	0.03	0.03	0.09
061	8.1 E	0.02	0.01	0.01	0.01	0.02	0.03	0.04	0.02
047	8.3 NE	0.03	0.31	BD	0.01	0.04	0.03	0.05	0.07
064	11.3 ENE	0.02	0.09	0.01	BD	0.02	0.02	0.05	0.03
048	12.1 NE	0.01	0.28	BD	0.01	0.02	0.02	0.05	0.06
Monthly Mean		0.02	0.18	BD	0.03	0.03	0.02	0.05	0.05
Phytotoxicology Upper Limit of Normal***					. . . Not established . . .				

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.01 ppm

TABLE 26: SEASONAL VARIATION OF MOLYBDENUM IN FORAGE, 1985

Site No.	Distance & Direction**	Molybdenum Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	BD	BD	BD	1.0	1.6	BD	1.0	BD
023	1.1 E	BD	BD	BD	1.0	1.6	BD	1.2	BD
024	2.0 NNE	1.4	BD	1.0	BD	BD	1.6	0.8	0.9
004	3.6 W	2.0	BD	1.4	1.6	2.6	1.6	2.2	1.7
044	4.6 E	BD	BD	BD	0.8	1.6	1.0	1.8	0.9
061	8.1 E	BD	1.2	BD	1.0	1.2	0.8	1.8	1.0
047	8.3 NE	1.0	1.0	BD	1.0	2.0	1.8	3.4	1.5
064	11.3 ENE	BD	BD	BD	1.8	1.6	0.8	BD	0.8
048	12.1 NE	1.0	BD	BD	1.8	1.3	1.8	1.0	1.1
Monthly Mean		0.8	BD	BD	1.2	1.5	1.1	1.5	1.0
Phytotoxicology Upper Limit of Normal***					. . . 6 ppm . . .				

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.8 ppm

TABLE 27: SEASONAL VARIATION OF IRON IN FORAGE, 1985

Site No.	Distance & Direction**	Iron Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	320	71	92	130	150	245	320	190
023	1.1 E	280	100	52	140	230	320	370	213
024	2.0 NNE	300	100	160	120	140	217	500	220
004	3.6 W	240	89	72	100	110	205	260	117
044	4.6 E	130	58	72	80	87	130	160	102
061	8.1 E	150	66	58	104	110	185	230	129
047	8.3 NE	90	92	41	57	73	130	160	92
064	11.3 ENE	71	54	98	84	76	94	90	81
048	12.1 NE	170	68	84	72	120	130	420	152
Monthly Mean		195	78	81	99	122	184	279	144
Phytotoxicology Upper Limit of Normal***		. . . 500 ppm . . .							

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 28: SEASONAL VARIATION OF SULPHUR IN FORAGE, 1985

Site No.	Distance & Direction**	Sulphur Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	0.28	0.24	0.18	0.33	0.33	0.37	0.28	0.29
023	1.1 E	0.32	0.44	0.13	0.36	0.38	0.33	0.30	0.32
024	2.0 NNE	0.35	0.31	0.26	0.44	0.44	0.40	0.27	0.35
004	3.6 W	0.32	0.40	0.32	**0.55**	0.44	0.38	0.43	0.41
044	4.6 E	0.28	0.26	0.28	**0.52**	**0.57**	0.49	0.35	0.39
061	8.1 E	0.31	0.20	0.49	0.46	**0.54**	0.32	0.41	0.39
047	8.3 NE	0.27	0.26	0.37	0.26	0.36	**0.58**	**0.61**	0.39
064	11.3 ENE	0.21	0.25	0.21	**0.53**	0.40	0.36	0.37	0.33
048	12.1 NE	0.28	0.21	0.20	0.45	0.43	0.37	0.37	0.33
Monthly Mean		0.29	0.29	0.27	0.43	0.43	0.40	0.38	0.36
Phytotoxicology Upper Limit of Normal***						. . . 0.50% . . .			

* Not washed, oven-dried, per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 29: ANNUAL AVERAGE FLUORIDE CONCENTRATION OF FORAGE, 1978 to 1985*

Site No.	Distance & Direction**	1978	1979	1980	1981	1982	1983	1984	1985	Mean
002	0.4 W	2	3	6	3	5	3	2	3	3
023	1.1 E	2	4	1	2	9	2	2	BD	3
024	2.0 NNE	3	3	1	2	5	3	4	3	3
004	3.6 W	3	3	2	2	4	2	4	3	3
044	4.6 E	3	3	1	3	5	2	2	BD	2
061	8.1 E	3	3	1	4	5	1	2	BD	3
047	8.3 NE	9	4	4	7	5	1	2	BD	4
064	11.3 ENE	3	4	1	4	5	2	2	BD	3
048	12.1 NE	4	4	1	4	7	4	4	BD	4
Mean		4	3	2	3	6	2	3	2	3
Phytotoxicology Upper Limit of Normal***		. . . 12 ppm . . .								

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 1 ppm

TABLE 30: ANNUAL AVERAGE SELENIUM CONCENTRATION OF FORAGE, 1978 to 1985*

Site No.	Distance & Direction**	1978	1979	1980	1981	1982	1983	1984	1985	Mean
002	0.4 W	0.15	0.10	0.05	BD	0.05	BD	0.10	BD	0.06
023	1.1 E	0.17	0.10	0.06	BD	0.06	BD	0.07	BD	0.06
024	2.0 NNE	0.47	0.10	0.06	BD	0.04	0.03	0.04	BD	0.10
004	3.[illegible] W	0.17	0.10	0.05	BD	0.05	BD	0.04	BD	0.06
044	4.6 E	0.24	0.10	0.13	BD	0.06	BD	0.07	BD	0.08
061	8.1 E	0.19	0.10	0.07	BD	0.04	0.03	0.05	0.03	0.07
047	8.3 NE	0.20	0.10	0.10	0.15	0.05	BD	0.06	BD	0.07
064	11.3 ENE	0.19	0.10	0.10	0.15	0.08	0.04	0.06	BD	0.09
048	12.1 NE	0.25	0.10	0.05	BD	0.14	0.11	0.06	BD	0.09
Mean		0.23	0.10	0.07	0.03	0.06	0.03	0.06	BD	0.08
Phytotoxicology Upper Limit of Normal***						. . . 0.5 ppm . . .				

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.03 ppm

TABLE 31: ANNUAL AVERAGE SULPHUR CONCENTRATION OF FORAGE, 1978 to 1985*

Site No.	Distance & Direction**	1978	1979	1980	1981	1982	1983	1984	1985	Mean
002	0.4 W	0.24	0.17	0.22	0.30	0.34	0.28	0.30	0.29	0.27
023	1.1 E	0.32	0.36	0.29	0.30	0.41	0.30	0.30	0.32	0.33
024	2.0 NNE	0.25	0.47	0.25	0.30	0.29	0.37	0.35	0.35	0.33
004	3.6 W	0.34	0.15	0.21	0.30	0.27	0.23	0.29	0.41	0.28
044	4.6 E	0.32	0.13	0.16	0.40	0.31	0.35	0.37	0.39	0.30
061	8.1 E	**0.66**	0.33	0.27	0.40	0.35	0.35	0.35	0.39	0.39
047	8.3 NE	0.35	0.23	0.27	0.20	0.32	0.32	0.39	0.39	0.31
064	11.3 ENE	0.32	0.28	0.23	0.20	0.32	0.29	0.35	0.33	0.29
048	12.1 NE	0.39	0.35	0.23	0.20	0.32	0.29	0.36	0.33	0.31
Mean		0.35	0.27	0.24	0.29	0.33	0.31	0.34	0.36	0.31
Phytotoxicology Upper Limit of Normal***						. . . 0.50% ppm . . .				

* Not washed, oven-dried, parts per cent

** km from the village of Nanticoke

*** See explanation in text

TABLE 32: ANNUAL AVERAGE IRON CONCENTRATION OF FORAGE, 1981 TO 1985*

Site No.	Distance & Direction**	1981	1982	1983	1984	1985	Mean
002	0.4 W	358	299	204	224	190	255
023	1.1 E	218	163	**645**	**1194**	213	487
024	2.0 NNE	137	118	148	201	220	165
004	3.6 W	148	104	248	358	117	195
044	4.6 E	84	85	83	137	102	98
061	8.1 E	226	85	99	143	129	136
047	8.3 NE	**610**	76	123	97	92	200
064	11.3 ENE	101	66	100	103	81	90
048	12.1 NE	255	127	112	154	152	160
Mean		237	124	188	290	144	198
Phytotoxicology Upper Limit of Normal***				. . . 500 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 33: VARIATION OF FLUORIDE IN FORAGE THROUGH THE GROWING SEASON, MEAN VALUES FROM 1982 to 1985

Site No.	Distance & Direction**	Fluoride Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	3	3	1	4	2	4	4	3
023	1.1 E	BD	4	1	5	1	3	BD	2
024	2.0 NNE	5	4	2	5	2	4	3	4
004	3.6 W	5	3	BD	4	2	4	3	3
044	4.6 E	BD	2	BD	3	1	3	1	2
061	8.1 E	2	BD	BD	3	1	3	BD	2
047	8.3 NE	BD	2	BD	4	BD	3	BD	2
064	11.3 ENE	2	2	BD	3	2	3	1	2
048	12.1 NE	4	2	BD	3	7	4	3	3
Monthly Mean		3	3	BD	4	2	3	2	3
Phytotoxicology Upper Limit of Normal***		. . . 12 ppm . . .							

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 1 ppm

TABLE 34: VARIATION OF SELENIUM IN FORAGE THROUGH THE GROWING SEASON, MEAN VALUES FROM 1982 to 1985

Site No.	Distance & Direction**	Selenium Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	BD	BD	BD	BD	BD	0.11	0.12	0.04
023	1.1 E	BD	BD	BD	BD	BD	0.08	0.09	0.04
024	2.0 NNE	BD	BD	0.03	BD	BD	0.07	BD	0.03
004	3.6 W	BD	0.05	BD	BD	BD	0.07	BD	BD
044	4.6 E	BD	0.03	BD	BD	BD	0.08	0.09	0.04
061	8.1 E	BD	0.05	BD	BD	BD	0.06	0.09	0.04
047	8.3 NE	BD	BD	BD	BD	BD	0.03	0.08	BD
064	11.3 ENE	BD	0.05	0.03	0.05	BD	0.07	0.07	0.04
048	12.1 NE	BD	0.05	BD	BD	0.13	0.14	0.11	0.07
Monthly Mean		BD	0.03	BD	BD	BD	0.08	0.08	0.04
Phytotoxicology Upper Limit of Normal***						. . . 0.50 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

BD Below analytical detection limit of 0.03 ppm

TABLE 35: VARIATION OF SULPHUR IN FORAGE THROUGH THE GROWING SEASON, MEAN VALUES FROM 1982 to 1985

Site No.	Distance & Direction**	Sulphur Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	0.35	0.27	0.19	0.28	0.30	0.38	0.31	0.30
023	1.1 E	0.36	0.33	0.20	0.34	0.33	0.41	0.31	0.33
024	2.0 NNE	0.37	0.29	0.23	0.35	0.41	0.43	0.45	0.36
004	3.6 W	0.37	0.28	0.21	0.31	0.29	0.33	0.39	0.31
044	4.6 E	0.32	0.24	0.26	0.35	0.48	0.47	0.41	0.36
061	8.1 E	0.34	0.24	0.28	0.34	**0.53**	0.43	0.38	0.36
047	8.3 NE	0.35	0.25	0.26	0.29	0.40	0.45	**0.56**	0.37
064	11.3 ENE	0.30	0.24	0.19	0.29	0.41	0.41	0.46	0.33
048	12.1 NE	0.37	0.23	0.20	0.32	0.42	0.40	0.37	0.33
Monthly Mean		0.35	0.26	0.22	0.32	0.40	0.41	0.40	0.34
Phytotoxicology Upper Limit of Normal***						. . . 0.50% . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 36: *VARIATION OF IRON IN FORAGE THROUGH THE GROWING SEASON, MEAN VALUES FROM 1982 to 1985*

Site No.	Distance & Direction**	Iron Concentration* Apr	May	June	July	Aug	Sept	Oct	Site Mean
002	0.4 W	240	112	81	102	163	371	490	223
023	1.1 E	210	370	97	133	**1610**	**560**	**1473**	**636**
024	2.0 NNE	225	157	170	120	137	179	330	188
004	3.6 W	225	162	127	169	217	332	417	236
044	4.6 E	103	108	84	69	88	111	185	107
061	8.1 E	120	82	55	79	97	166	253	122
047	8.3 NE	83	116	46	49	103	113	180	99
064	11.3 ENE	74	91	65	105	73	96	117	89
048	12.1 NE	130	119	98	82	143	130	297	143
Monthly Mean		157	146	91	101	292	229	416	205
Phytotoxicology Upper Limit of Normal***						. . . 500 ppm . . .			

* Not washed, oven-dried, parts per million

** km from the village of Nanticoke

*** See explanation in text

TABLE 37: COMPARISON OF NANTICOKE FORAGE CHEMICAL CONCENTRATIONS WITH VETERINARY LITERATURE DIETARY TOXICITY LEVELS FOR CATTLE

Element	Nanticoke Forage Concentrations*			Toxicity Levels***	
	Maximum Detected	Mean Level	Upper Limits of Normal**	Ref. 1	Ref. 2
As	0.30	0.17	NE	50	NL
F	12	3	12	40	100
Se	0.47	0.07	0.50	2	5
Cl	2.04%	0.53%	1.00%	NL	NL
S	0.66%	0.31%	0.50%	NL	NL
Pb	4	3	20	NL	100
Cd	0.1	<0.1	0.5	0.5	50
Mo	3.4	1.0	6	10	5
Hg	0.47	0.03	NE	2	4
Cr	3	1	5	1000	NL
V	1	<1	6	50	NL
Cu	11	5	7	100	NL
Zn	50	36	40	500	5000
Ni	2	1	5	50	1500
Fe	3600	197	500	1000	4000

* Parts per million or per cent, dry weight, not washed

** Described in text

*** References and significance of these levels are cited in text

NL Not listed
NE Not established

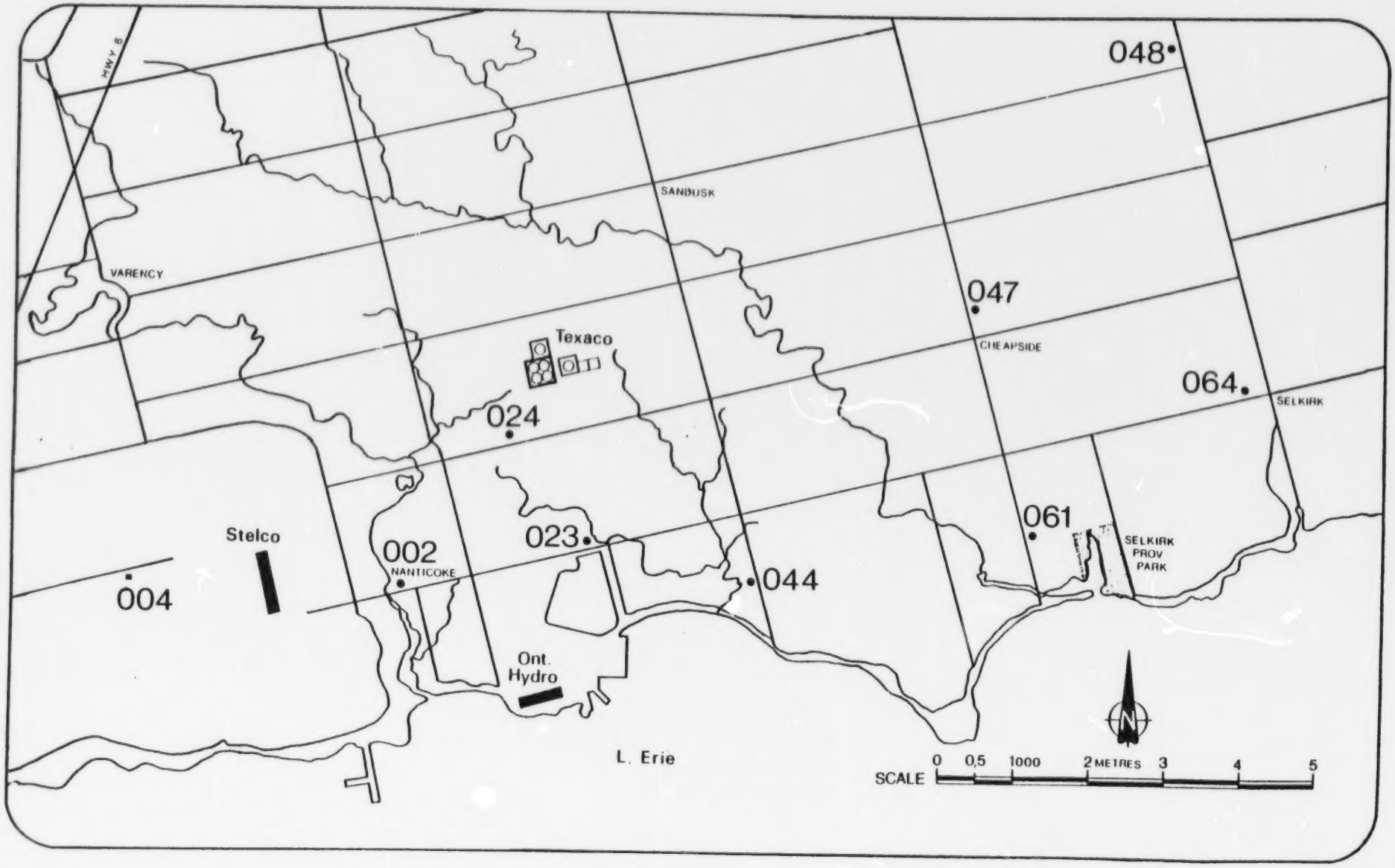

Figure 1: Location of 9 common forage collection sites.

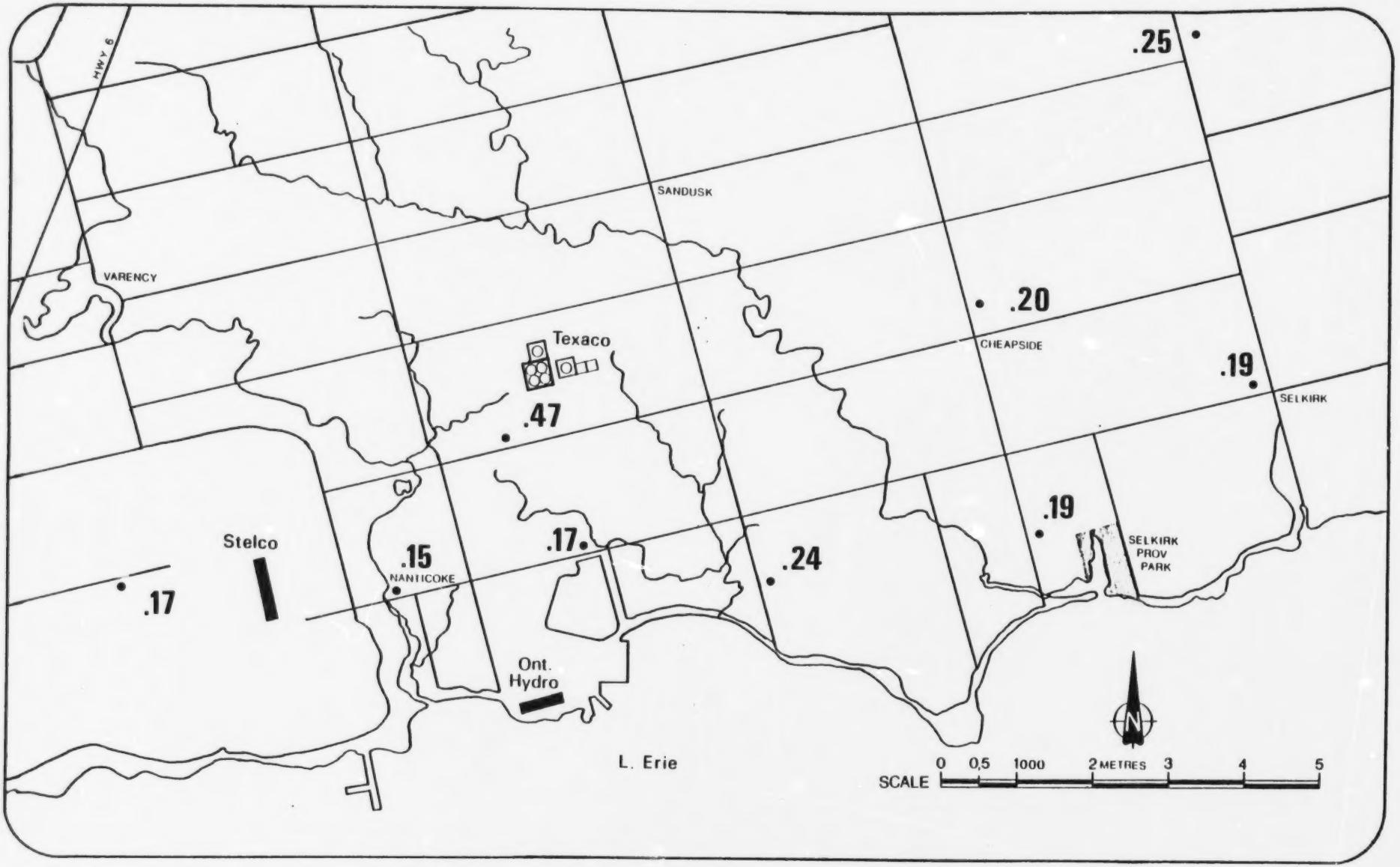

Figure 2: Selenium concentration of forage. Mean of replicate samples collected in July, 1978. Data are ppm, dry weight, not-washed.

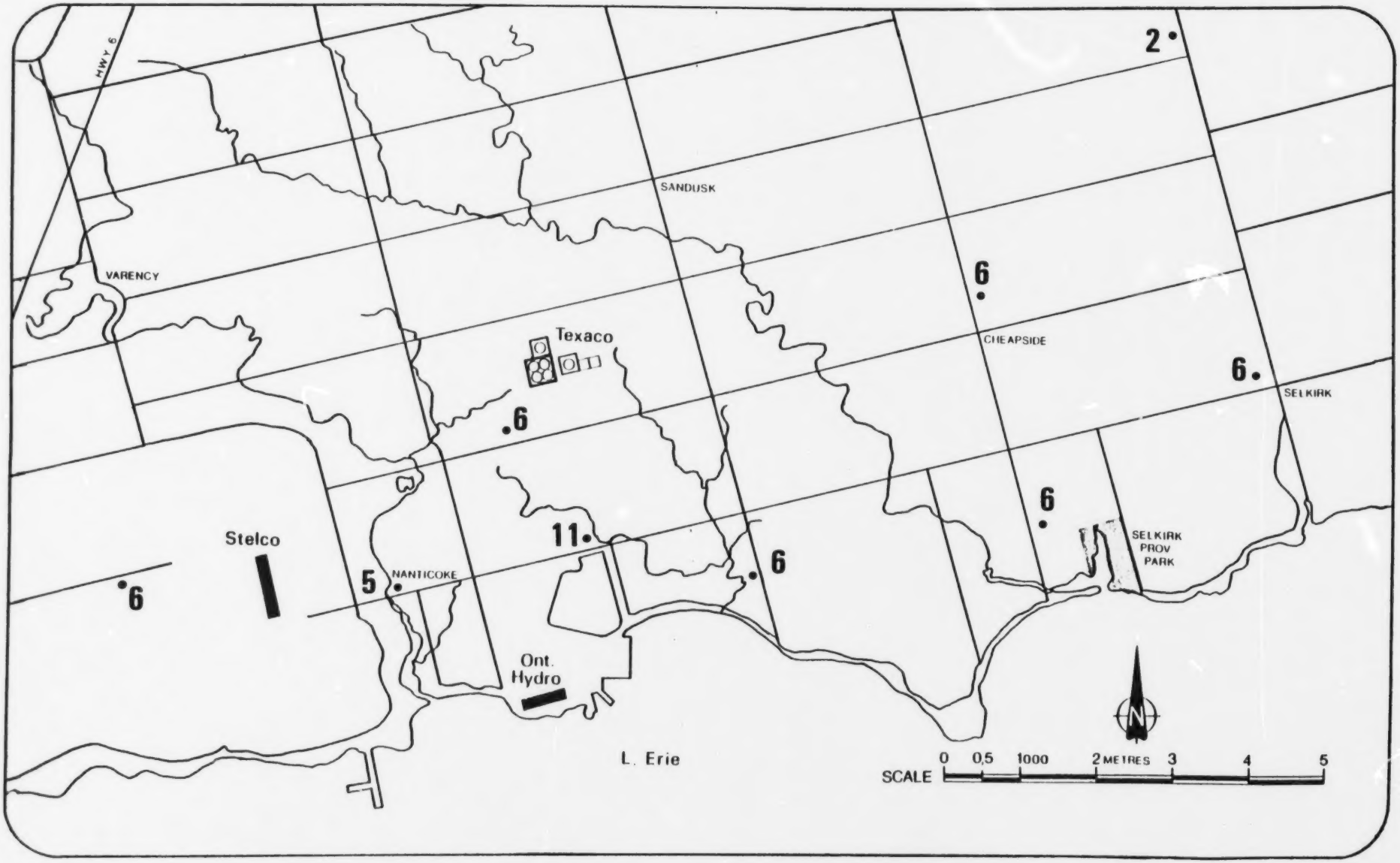

Figure 3: Fluoride concentration of forage. Mean of replicate samples collected in July, 1982. Data are ppm, dry weight, not-washed.

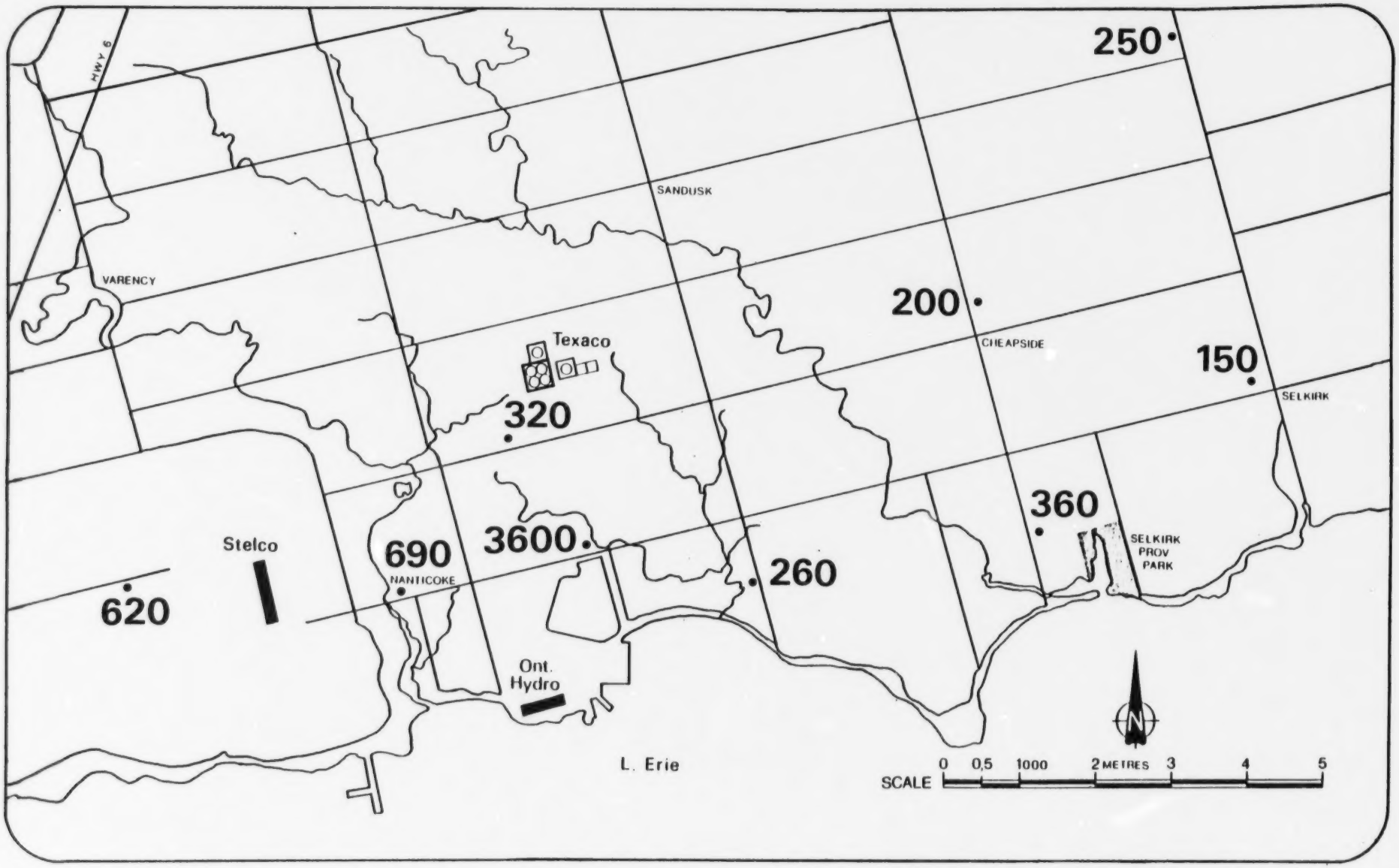

Figure 4: Iron concentration of forage. Mean of replicate samples collected in October, 1984. Data are ppm, dry weight, not-washed.

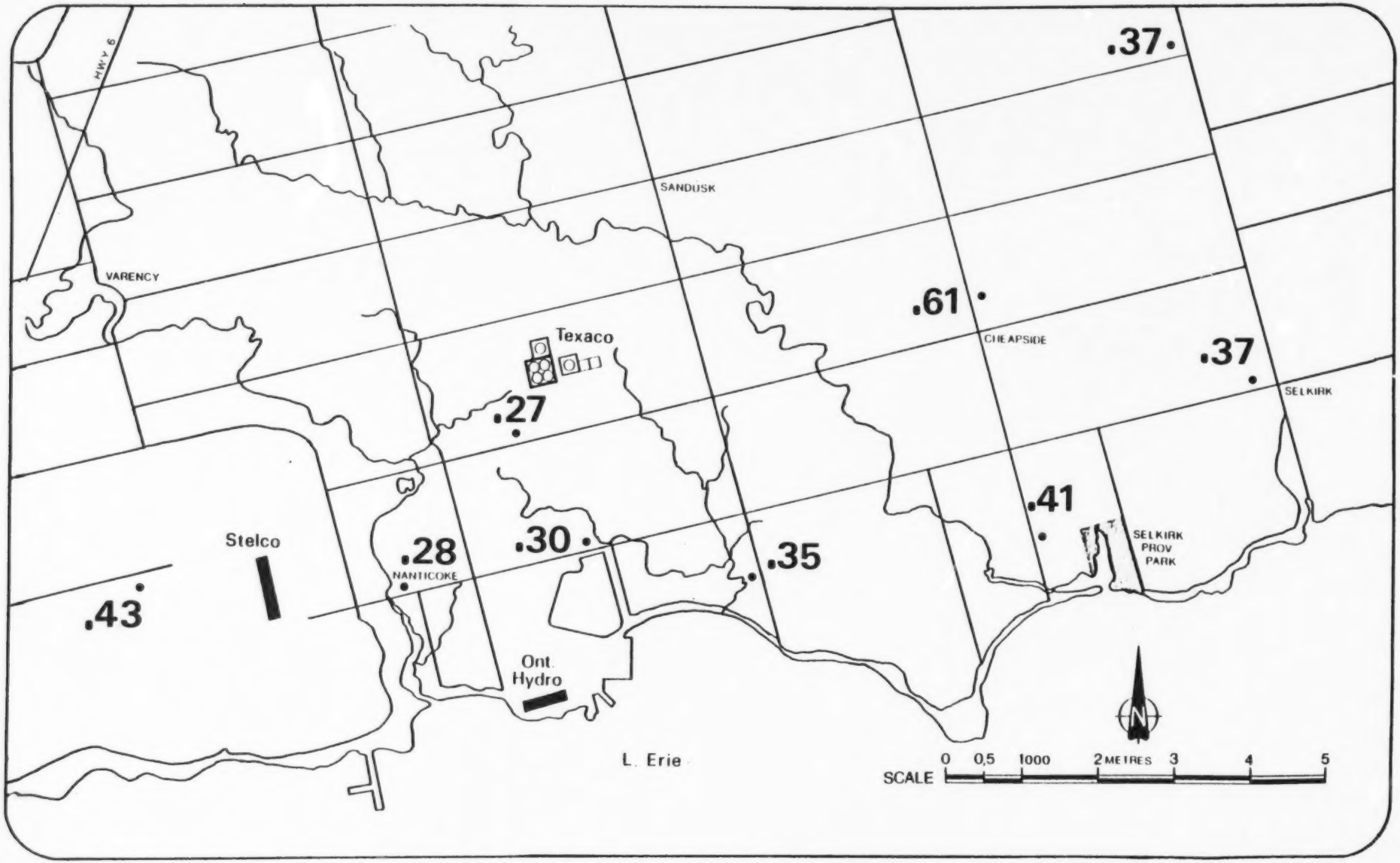

Figure 5: Sulphur concentration of forage. Mean of replicate samples collected in October, 1985 Data are %, dry weight, not-washed.

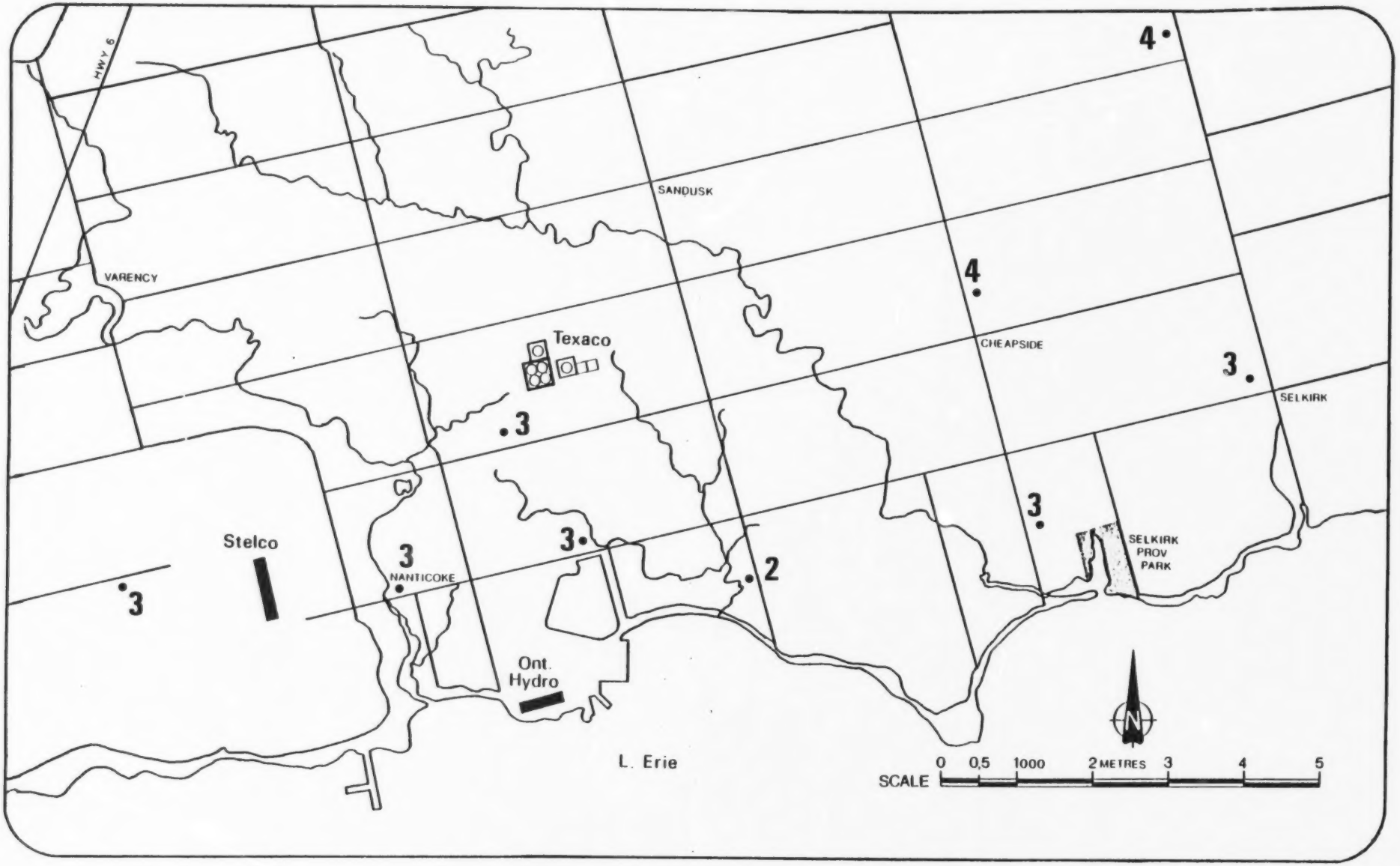

Figure 6: Mean Fluoride concentration of forage, 1978 to 1985. Data are ppm, dry weight, not-washed.

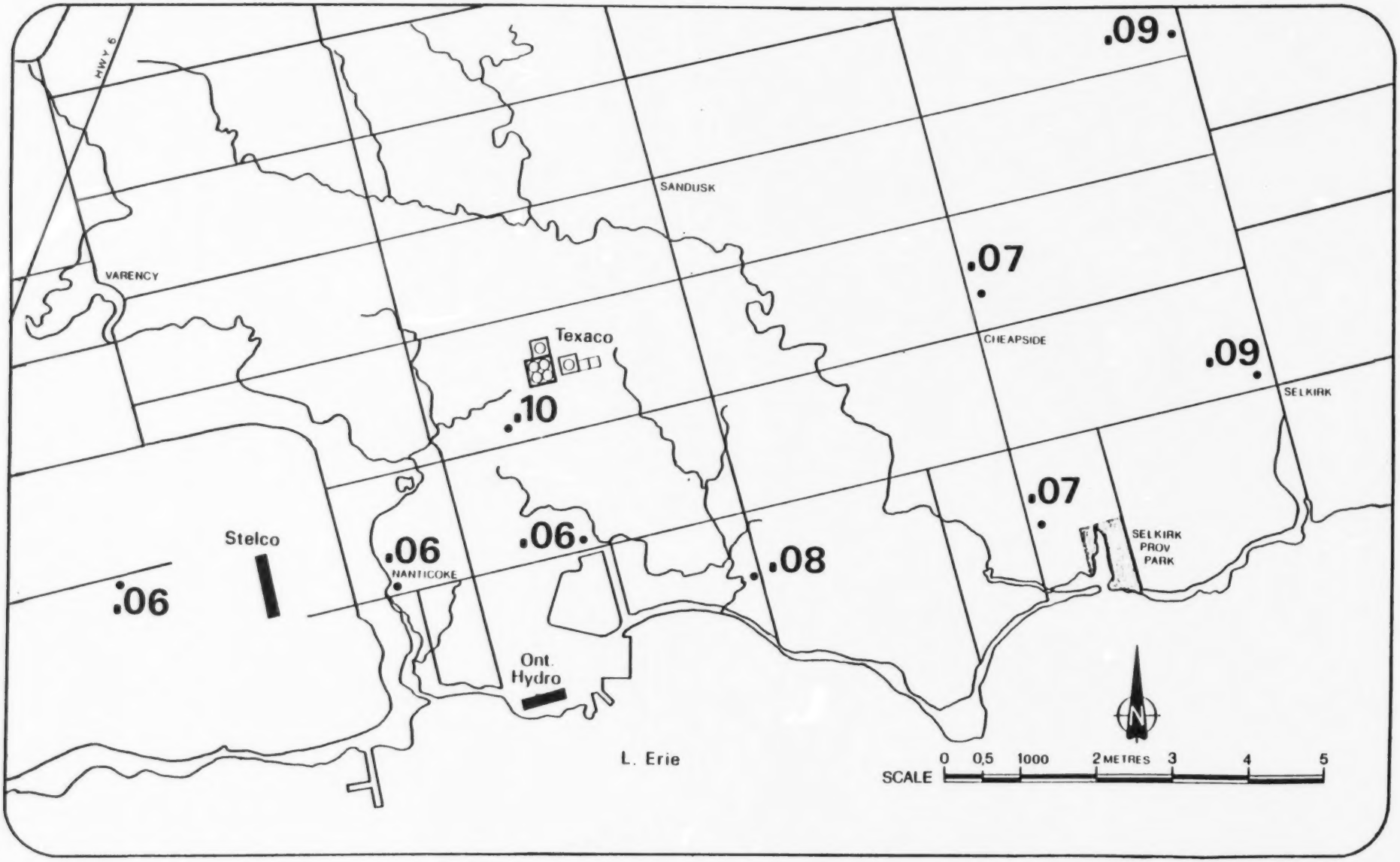

Figure 7: Mean Selenium concentration of forage, 1978 to 1985. Data are ppm, dry weight, not-washed.

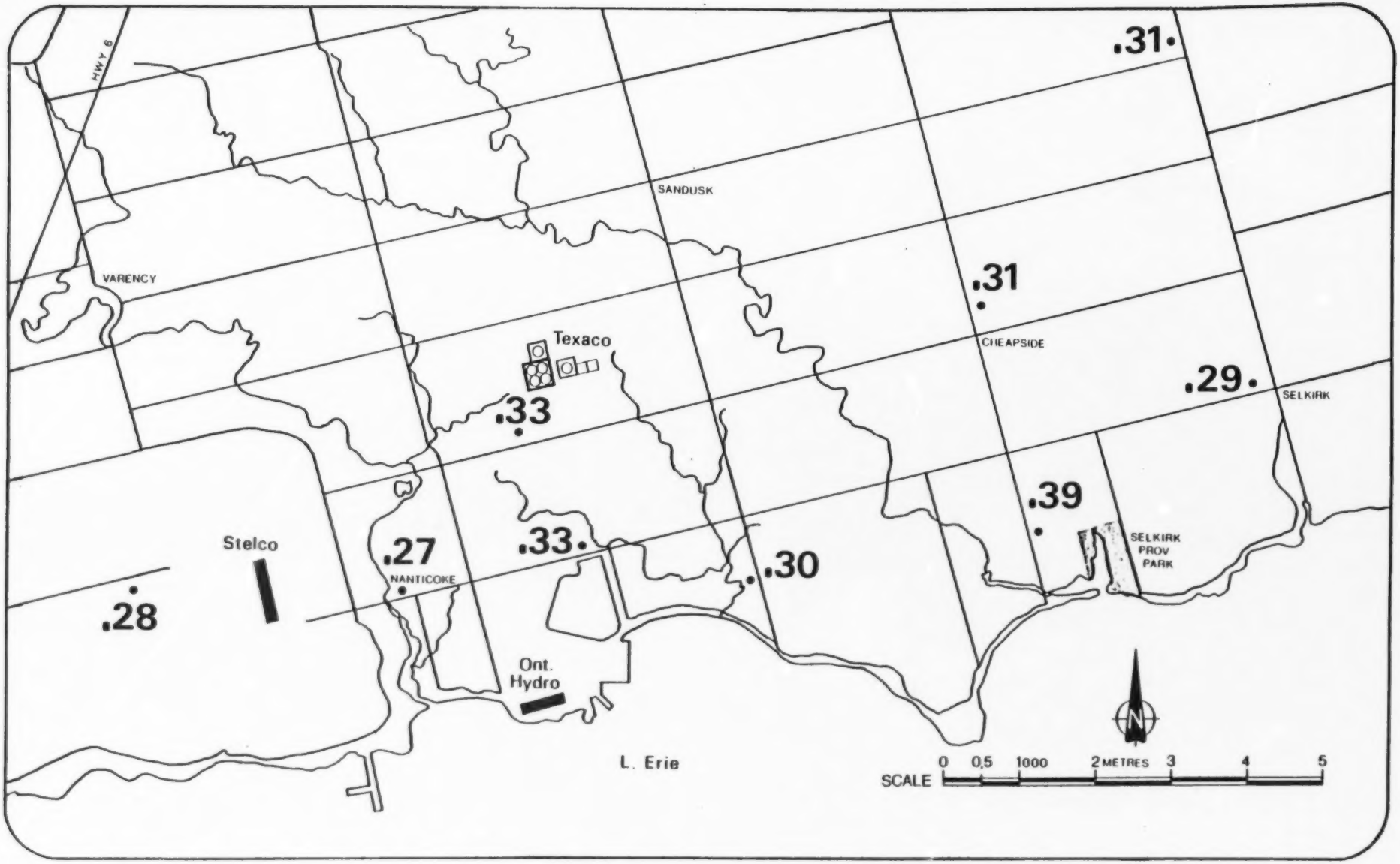

Figure 8: Mean Sulphur concentration of forage, 1978 to 1985. Data are %, dry weight, not-washed.

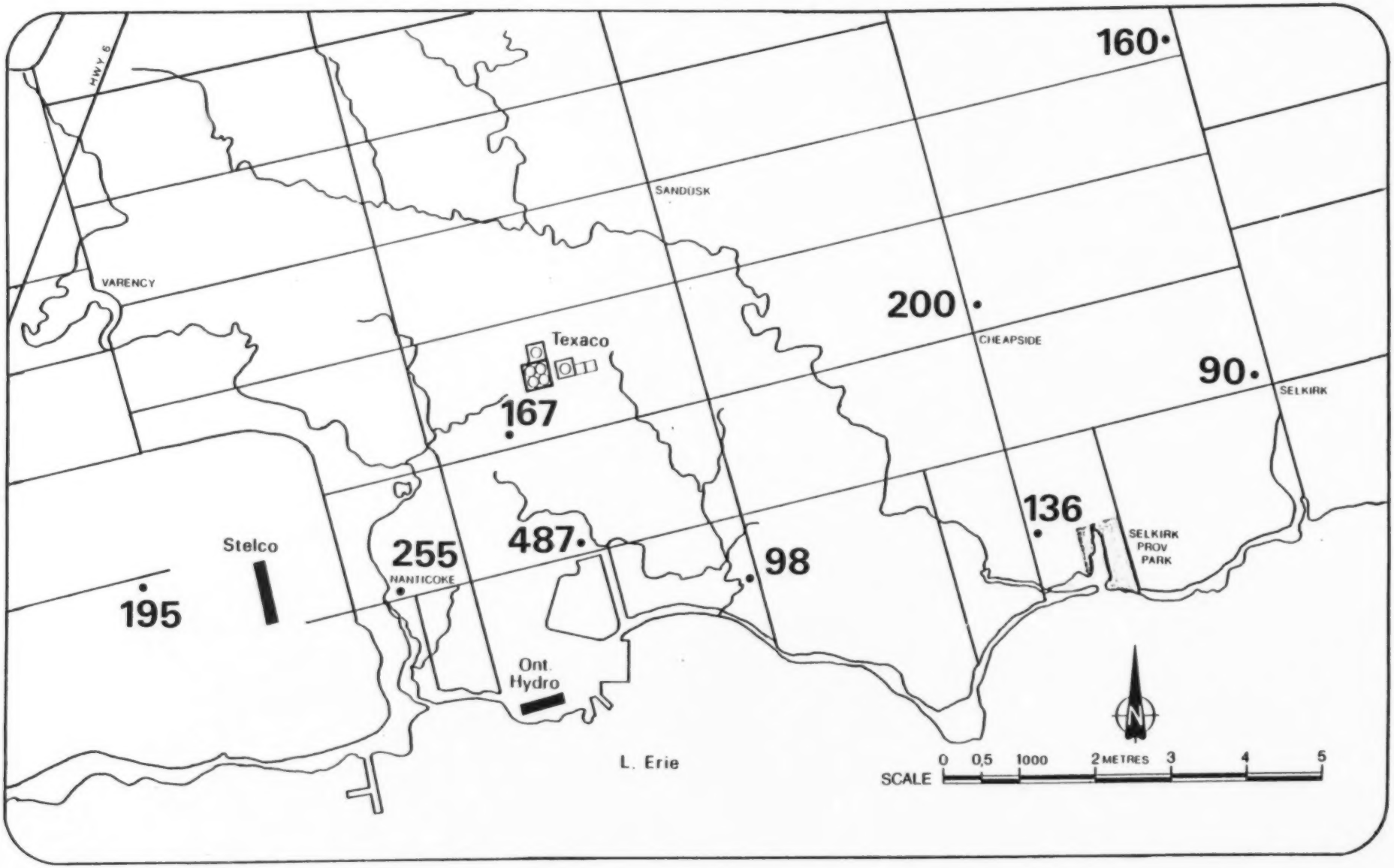

Figure 9: Mean Iron concentration of forage, 1981 to 1985. Data are ppm, dry weight, not-washed